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Review Article

Usability Barriers for Elderly Users in Smartphone App Usage: An Analytical Hierarchical Process-Based Prioritization

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With the latest technology, smartphone's profound impact may be valuable for the users in different age groups, but the elders always face difficulties while adopting the technology. The usability of a smartphone application is essential when the target audience is elderly users, as the designer did not satisfy the specific requirements. The importance of smartphone application and the issues that the elders are facing in using smartphones have motivated us to provide a list of barriers that could negatively impact the usability of smartphone applications in elderly people. This research focused on identifying the barriers that affect the usability of smartphones, especially among elders. A systematic literature review (SLR) was used to identify and validate the barriers. After that, we apply the analytic hierarchy process (AHP) on identified barriers of all barriers' groups to find out their relative importance. A total of fifteen barriers were identified through the SLR approach, and the barriers were then classified and assigned to one of the five categories. It is expected that the barriers that have been recognized will help the designers of smartphone applications in the early stages of designing applications. The result of the study will help in dealing with the issues related to the elder community and will make the designers develop smartphone applications accordingly.

1. Introduction

The advancement in smartphones plays a vital role in everyday life because of their connection and computational power. The smartphone has a lot of potentials to perform various tasks; apart from making a call or sending texts, these tasks include Internet access, information sharing, and multimedia [1]. According to Statista (a leading provider of market and consumer data), the number of smartphones is about 3.5 billion in 2020. Worldwide data show that one in every five people owns smartphones [2–4].

Smartphones play a crucial role in the lives of both the elders and the youngsters. Primarily, users use trials when operating their device and adopt as a technology native; however, the elderly are not much familiar with smartphone technology and face difficulty while using the device [5].

The user interface of the existing smartphones is primarily complex and is developed by targeting mainly the young people and not the elders [6]. Elderly users are neglected in the design phase of smartphone applications, and the designers do not concentrate on the needs and requirements of elderly people [7–9]. Although elderly users are willing to adopt the technology that helps them keep their quality of life due to the complex interface, they cannot avail the benefits of smartphones. As a result, the reason for different issues is discussed from two different views. The first is their age-related problems, i.e., cognitive, physical abilities, memory decline, mental models, and sensory function, making it harder from them to interact with new technologies [10, 11].

The second problem is software design; the designers do not carefully design applications regarding elderly user needs and requirements. The designer should come with a concrete solution that could help elderly people to interact with smartphone applications. Previously, limited attention has been given by the designer to develop smartphone applications for elderly users. There is a research gap in addressing the specific needs of elderly users related to smartphone applications [12].

Usability becomes essential when it comes to a smartphone application. A high level of usability is critical when the target group is elderly users because they might have different disabilities [11]. A usability evaluation approach for an educational application named Crossword was presented in [13]. They concluded that usability issues are widely shared among the elderly regarding smartphone applications. They aim that the obtained evaluation can be helpful for application developers and smartphone designers. In another study, the various available smartphone applications for elderly healthcare were investigated [14]. In literature, it was reported that the usability of smartphone applications is the most common challenge [15, 16]. A systematic literature review on identifying the usability issues of smartphones was presented in [17]. They divided the usability problems into three major groups: visual limitations, psychomotor limitations, and cognitive limitations. Based on the above discussion, the study's objective is to examine the barriers to improve the usability of smartphone applications for elderly people.

In this study, we identify barriers that could harm the usability of a smartphone application for the elderly users. The SLR results show how to recognize these barriers and improve the usability of smartphone applications. The study focused on addressing the following research questions:

RQ1. What barriers are discussed in the literature that could impact the usability of smartphone applications?

***RQ2**. What are the most important barriers that have been identified in literature?*

RQ3. How can the barriers be assigned and categorized?

These research questions aim to identify the barriers to the interaction of elderly users with smartphone applications to improve the effectiveness of smartphone applications. Most of the studies have highlighted different aspects of smartphone applications for elderly users that hinder the adoption [18–22]. The usability of relevant problems in the context of elderly age people has been previously ignored. For example, the elderly still faced interaction problems with new technologies, and the adoption rate is low. It is vital to consider how smartphone applications can meet the usability needs and wants of the elderly population. The importance of smartphone applications and the issues that the elders face in using smartphones have motivated us to provide a list of barriers that could negatively impact the usability of smartphone applications in elderly users.

2. Research Methodology

The study consists of the SLR approach; the SLR is a secondary study in which primary studies are examined in an iterative way to identify, analyze, and explore evidence relating to research [12].

2.1. Systematic Literature Review. The SLR is a way to evaluate and interpret all available research relevant to a specific research issue or subject. SLR is used by inclusion and exclusion techniques to investigate, categorize, and evaluate existing literature related to a particular area of research. According to Kitchen ham et al. [23–25], there are three main phases of the SLR: planning, conducting, and reporting the review, as shown in Table 1.

2.1.1. Phase 1: Planning the Review

Research Questions. The present study focused on the usability barriers of the smartphone application for the elderly users. The following research questions were addressed in this study:

RQ1. *What are the barriers discussed in the literature that could impact the usability of smartphone applications?*

RQ2. *What are the main significant barriers identified in the literature?*

RQ3. *How to assign values and categorize the identified barriers?*

Data Sources. Appropriate databases and recommendations were identified in [26]. The data sources contained

(i) IEEE Xplore
(ii) ACM Digital Library
(iii) Springer Link
(iv) Science Direct
(v) Google Scholar

Search Strings. Search strings were prepared using keywords (and their alternatives) derived from existing literature and research questions. We use different operators "OR "and "AND" for linking keywords to search strings as used by related research works [27, 28]. The digital database libraries have been explored using the strings mentioned in Table 2.

Inclusion Criteria. The nominated articles written or published in English should be available in full text. We consider articles that discuss barriers to the usability of a smartphone application concerning elderly users.

Exclusion Criteria. Articles that do not explicitly discuss usability in the context of the elderly and barriers were excluded.

Quality Criteria for Study Selection. Quality assessment (QA) is needed to emphasize the significance of the selected articles when discussing the outcomes and while guiding the interpretation of the outcomes [23]. The quality of each

Table 1: Phases of SLR.

Phases	Steps
Planning	Research question data sources' inclusion and exclusion criteria and search strings' quality criteria for study selection
Conducting	Primary study selection, data extraction, and data synthesis
Reporting	Documenting the extracted results

Table 2: Search strings.

Scope	Strings
Mobile context	(Smartphone∗ OR "mobile phone" OR "mobile device") AND
Software	(Application OR app OR technology) AND
Users context	(Elderly∗ OR "older adults") AND
Usability topic	(Usability OR "user interface" OR" human-computer interaction" OR HCI) AND
Barriers	(Barrier OR challenges OR problem OR issues OR difficulties) AND
Research type	(Empirical OR questionnaire OR survey OR "case study")

selected paper is checked based on a predefined quality assessment checklist, as shown in Table 3 [27,28]. The evaluation score was carried out from QA1 to QA4.

(i) Articles that addressed the entire checklist questions were assigned to score 1

(ii) Articles that not addressed checklist questions were assigned to score 0

(iii) Articles that addressed some of the questions from the checklist were assigned to score 0.5

2.1.2. Phase 2: Conducting the Review. Primary Study Selection. The research articles for the primary study were refined by using the tollgate approach [29]. This is a five-phase approach, as described in Table 4 and shown in Figure 1.

(i) Phase 1: finding relevant articles based on the search terms

(ii) Phase 2: inclusion and exclusion of articles based on their title and abstract

(iii) Phase 3: inclusion and exclusion based on introduction and conclusions

(iv) Phase 4: inclusion and exclusion based on full text read

(v) Phase 5: the final selection of the primary study is to be included in SLR

At the beginning of 1930, it was a trend to select and originate articles based on different search strings and the inclusion/exclusion criteria regarding some topics. Later, the tollgate approach has been used for article selection.

In this work, we have used the tollgate approach that led to the inclusion of 53 articles as a primary study. The tollgate approach is based on selected articles and then evaluated

Table 3: Quality assessment.

QA questions	Checklist questions
QA1	Does the article mention any barriers concerning elderly users?
QA2	Is the data related to the usability of smartphone applications for the elderly?
QA3	Are the results discussed in the article related to research questions?
QA4	Does the study publish in a recognized publication?

Table 4: Articles' selection using the tollgate approach.

Databases	Ph1	Ph2	Ph3	Ph4	Ph5
ACM digital library	831	250	119	17	15
IEEE Explorer	585	160	24	12	8
Science Direct	341	205	164	35	12
Google Scholar	33	29	21	21	15
Springer	140	70	72	5	3
Total papers	1930	714	400	90	53

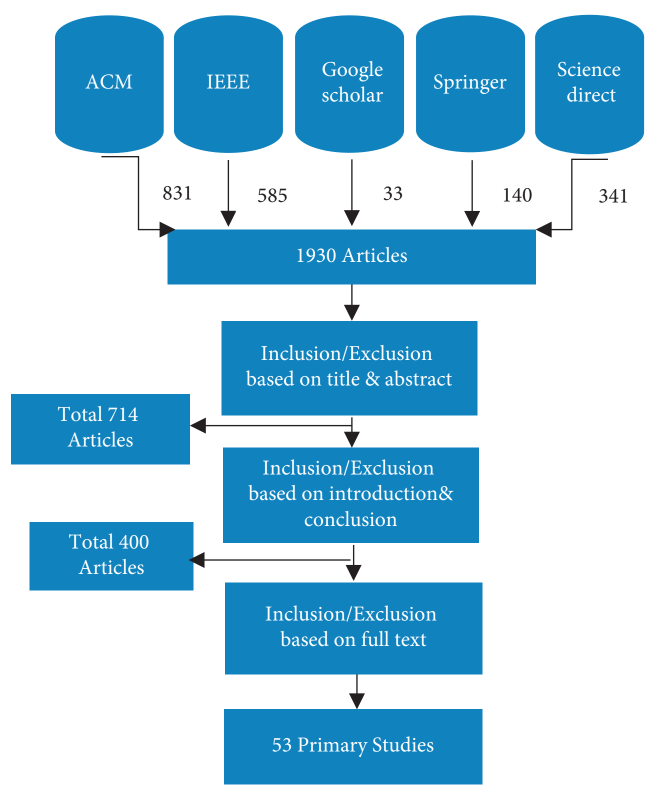

Figure 1: Tollgate approach for article selection.

using quality evaluation criteria. The list of the primary selected studies can be found in Table 5. We have labeled all the primary selected articles as **[LT]**, followed by a digit for indicating their use in the SLR.

Data Extraction. In this step, we extracted the title of each article, type of article study, and methods of their research and assigned scores to them.

Table 5: Selected primary studies using SLR.

Tracking id	Article title	Study type	Research method	Year	QA1	QA2	QA3	QA4	Total
LT 1	Design patterns to enhance accessibility and use of social applications for older adults [41]	Journal	Heuristic evaluation technique	2015	1	1	1	1	4
LT 2	Multi-layered interfaces to improve older adults' initial learnability of mobile applications [9]	Journal	Experimental	2010	1	1	0.5	1	3.5
LT 3	How older adults learn to use mobile devices: Survey and field investigation [5]	Journal	Survey and field investigation	2012	1	0.5	0.5	1	3
LT 4	Process of design and usability evaluation of a telepsychology web and virtual reality system for the elderly: Butler [20]	Journal	Survey	2013	1	1	0	1	3
LT 5	Older adults' attitudes and barriers toward the use of mobile phones [22]	Journal	Descriptive study/ questionnaire	2016	1	1	1	0.5	3.5
LT 6	Mobile apps for older users–The development of mobile app repository for older people [7]	Conference	Review the usability issue	2014	1	1	0	0.5	2.5
LT 7	Understanding the process of learning touch screen mobile applications [42]	Conference	Survey questionnaire	2013	1	0	0	1	2
LT 8	Age-related differences in the initial usability of mobile device icons [43]	Journal	Qualitative exploratory study	2009	1	1	0.5	1	3.5
LT 9	On some aspects of improving mobile applications for the elderly [44]	Conference	Experimental study	2007	1	0.5	0.5	1	3
LT 10	Adaptive training interfaces for less-experienced, elderly users of electronic devices [45]	Journal	Experimental study	2013	1	1	0.5	1	3.5
LT 11	Investigating the usability of PDAs with aging users [46]	Conference	Pilot study/interviews and questionnaires	2013	1	0	0	0.5	1.5
LT 12	Elderly text-entry performance on touchscreens [47]	Conference	Empirical study	2012	1	1	1	0.5	3.5
LT 13	A study of the use of mobile phones by older persons [16]	Conference	A mixed method of qualitative and quantitative approaches	2006	1	1	0.5	1	3.5
LT 14	Acceptance of mobile technology by older adults: A preliminary study [48]	Conference	Empirical study	2016	1	1	0.5	1	3.5
LT 15	Accessibility to mobile interfaces for older people [49]	Conference	Survey	2014	1	1	1	1	4
LT 16	Age-related difference in the use of mobile phones [50]	Conference	Survey and questionnaire	2014	1	1	1	1	4
LT 17	Factors affecting the adoption and use of mobile devices and services by elderly people – results from a pilot study [51]	Conference	Empirical study/ interview	2006	1	1	1	0.5	3.5
LT 18	The use of mobile phones by older adults: A malaysian study [8]	Conference	Questionnaire/survey	2008	1	1	1	0.5	3.5
LT 19	How older adults meet complexity: Aging effects on the usability of different mobile phones [52]	Journal	Experiment	2005	1	0.5	0.5	1	3
LT 20	Usability problems experienced by elderly users in-home healthcare systems [53]	Journal	Empirically-based usability evaluation studies	2014	1	1	0.5	0.5	3
LT 21	Older adults' use of smartphones: An investigation of the factors influencing the acceptance of new functions [54]	Journal	Questionnaire/survey	2013	1	1	1	1	4
LT 22	Use and design of handheld computers for older adults: A review and appraisal [55]	Journal	Empirical study	2012	1	1	1	1	4
LT 23	Design for elderly-friendly: Mobile phone application and design that suitable for elderly [56]	Journal	Experimental	2014	1	0	0	1	2
LT 24	Older people and mobile phones: A multi-method investigation [15]	Journal	Qualitative and quantitative method	2008	1	1	1	1	4

Table 5: Continued.

Tracking id	Article title	Study type	Research method	Year	QA1	QA2	QA3	QA4	Total
LT 25	Recommendations for the development of web interfaces on tablets/iPods with emphasis on elderly users [57]	Conference	Qualitative and exploratory	2015	1	1	1	1	4
LT 26	User interfaces with a touch of grey?–Towards a specific UI design for people in the transition age [58]	Conference	Qualitative empirical study	2015	1	0.5	0.5	1	3
LT 27	Senior-friendly icon design for the mobile phone [59]	Conference	Survey	2008	1	1	1	0.5	3.5
LT 28	A qualitative study to identify icons characteristics on mobile phones applications interfaces [18]	Conference	Qualitative exploratory study	2013	1	0.5	0.5	1	3
LT 29	A study of smartphone usage and barriers among the elderly [60]	Conference	Qualitative/ semistructured interview	2014	1	1	1	1	4
LT 30	Older people and their use of mobile devices: Issues purposes and context [61]	Conference	Qualitative/focus group	2013	1	0.5	0	0.5	2
LT 31	Users' perspective of smartphone platforms usability: An empirical study [10]	Conference	Empirical study/ questionnaire	2014	1	1	1	0.5	3.5
LT 32	Usability challenges in mobile application [27]	Journal	LR	2013	1	1	1	1	4
LT 33	Which factors form older adults' acceptance of mobile information and communication technologies? [62]	Conference	Experimental study	2015	1	1	1	1	4
LT 34	Determining the effect of menu element size on the usability of mobile applications [63]	Conference	Experimental study/ questionnaire	2015	1	0.5	1	1	3.5
LT 35	The interaction experiences of visually impaired people with assistive technology: A case study of smartphones [64]	Journal	Empirical study	2016	1	0.5	0.5	1	3.5
LT 36	Smart but not adapted enough: Heuristic evaluation of smartphone launchers with an adapted interface and assistive technologies for older adults [65]	Journal	Exploratory/empirical study	2018	1	1	0.5	1	3.5
LT 37	Design and evaluation of a mobile user interface for older adults: Navigation, interaction, and visual design recommendations [66]	Conference	Empirical study	2014	1	1	1	1	4
LT 38	Older people, assistive technologies, and the barriers to adoption: A systematic review [67]	Journal	SLR	2016	1	1	1	1	4
LT 39	Investigating the problems faced by older adults and people with disabilities in online environments [68]	Journal	Evaluation of website	2007	1	0	0	1	2
LT 40	Empirical studies on the usability of mHealth apps: A systematic literature review [2]	Journal	SLR	2015	1	1	0.5	1	3.5
LT 41	Technology use by older adults and barriers to using technology [21]	Conference	Survey	2014	1	1	1	0.5	3.5
LT 42	Older people, mobile device and navigation [69]	Journal	Case study	2004	1	0.5	0.5	0.5	2.5
LT 43	Design principles to accommodate older adults [70]	Journal	Empirical	2012	1	1	1	1	4
LT 44	Personal and other factors affecting the acceptance of smartphone technology by older Chinese adults [71]	Journal	Structured questionnaire/ interview	2016	1	1	1	1	4
LT 45	Factor influencing the use of smartphones by malaysian elderly	Journal	Interview and survey	2014	1	1	1	1	4
LT 46	Improving the accessibility of tactile interaction for older users: Lowering accuracy requirements to support drag-and-drop [72]	Conference	Empirical study	2015	1	1	1	1	4
LT 47	Early user involvement in the development of information technology-related products for older people [73]	Conference	Questionnaire/focus group/interview	2004	1	1	0	1	3

Table 5: Continued.

Tracking id	Article title	Study type	Research method	Year	QA1	QA2	QA3	QA4	Total
LT 48	Perspective: Older adults' adoption of technology: An integrated approach to identifying determinants and barriers [12]	Conference	Survey study	2015	1	1	0.5	0.5	3
LT 49	Usability evaluation of the smartphone user interface in supporting elderly users from the experts' perspective [74]	Journal	Heuristic evaluation	2018	1	1	0.5	1	3.5
LT50	Development of a framework to improve the use of mobile devices by the elderly [75]	Conference	Survey	2018	1	1	1	0.5	3.5
LT 51	Aging barriers influencing mobile health usability for older adults: A literature-based framework (MOLD-US) [76]	Journal	Literature review	2018	0.5	1	0	1	2.5
LT 52	Mobile health for older adult patients: Using an aging barriers framework to classify usability problems [30]	Journal	Case study	2019	1	1	0.5	1	3.5
LT 53	Older adults' use of the mobile device: Usability challenges while navigating various interfaces [6]	Journal	Empirical study/ interviews	2019	1	1	1	1	4

Data Synthesis. Usability barriers for smartphone applications were created from 53 articles. The extracted data from the selected article were used for evaluating research questions.

2.1.3. Phase 3: Reporting the Review. Quality Attributes. Table 5 illustrates the score in Table 4 for all the articles selected from the four questions of quality assurance. For each article, the final QA score was the sum of the score assigned for each QA question.

Temporal Distribution of the Selected Primary Studies. Figure 2 shows the total of selected primary studies and their publication year, research methods, and the decade of the 53 articles. It is clear that 14 articles were published in the first decade (2004–2010), and 39 articles (2011–2020) were published in the second decade.

Research Methods. The articles selected as the primary study consists of 18 questionnaire surveys (QS), 10 empirical studies (ES), 10 mixing methods (MM), 8 experimental studies (ES), 4 SLR, 3 heuristic assessments (HE), 1 review, and 1 case study. Most researchers adopt a survey questionnaire approach to conduct empirical studies on the usability of smartphone device applications for the elderly.

3. SLR Results

In this section, the results of the SLR have been described.

3.1. Identified Barriers Using an SLR. The SLR approach was used for identifying a total of 53 primary research articles. There were 15 barriers extracted from all these articles. In response to RQ1, the percentages and frequencies of the extracted barriers are established and shown in Table 6, and the barriers along with their frequencies are shown graphically in Figure 3.

BA1 **(small font, screen size, font type, buttons,** and **color contrast)** was found to be the most common barrier to the usability of smartphone applications around 76% [31]. A study in [LT4] proposes that usability problems could be caused due to various issues such as small font size (sensory problem), confusing menus (cognitive problem), and small keys with small gaps (sensory and motor problem). The barriers include the prolonged search for icons and their identification difficulties, problems with font type color, low voice quality, forgetting the learned things, quick changes in technology, and the need for software update.

In [LT6], the author states that elderly users take a huge time in completing tasks on their smartphones because they face problems such as reading information on a small size screen of their smartphone devices.

The SLR result revealed that BA9 **(menu and navigation issues)** had been the second most frequently cited barrier (63%). [LT34] concluded that the element size has a direct correlation to increased user preference and usability. In [LT33], it was stated that elderly users face low spatial abilities, experience confusion, and feel "get lost" when they navigate the menu of smartphones. [LT43] demonstrates that navigation buttons should have frequent consistency, the core functions must be visible and accessible, and finding and correcting errors need to be easy. The authors in [LT37] demonstrate that, for older adults, it is important to have an improved interface of the menus and other navigation objects. They state that the functional complexity of smartphones may increase the complexity of their different menus.

BA3 **(lack of experience and knowledge)** is mentioned by 56% of the selected articles. A study in [LT3] reported the problems that elderly users are facing while experiencing the existing smartphones. They investigated that such problems bring low usage of smartphone applications by the respective population. Also, in this survey, they reported that only 49% of the elderly population owns a smartphone that is much low than the whole surveyed population which was 82%. The

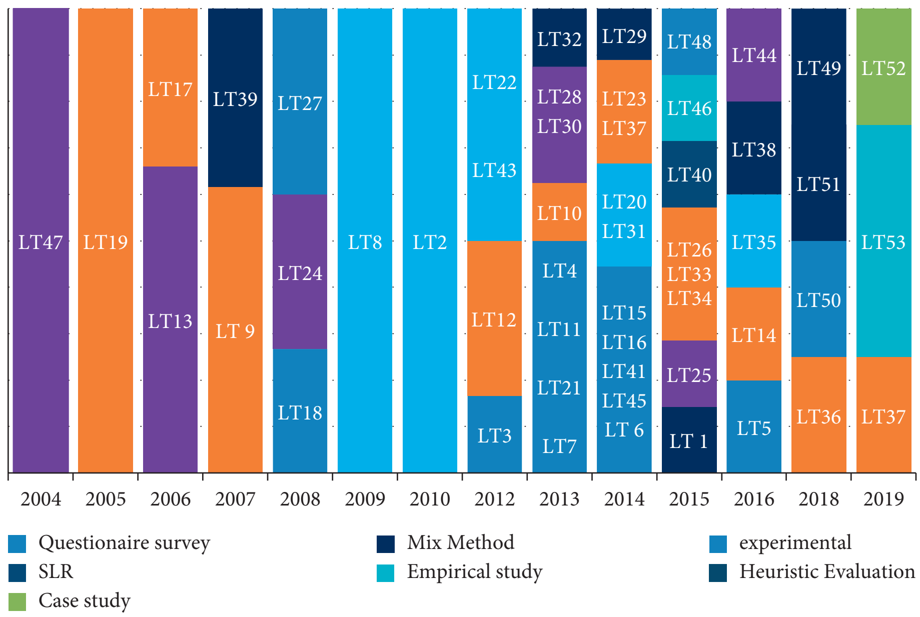

Figure 2: Temporal distribution of the selected primary studies.

Table 6: Barriers identified using SLR.

S. no.	Identified barriers	Frequency	S. no.	Identified barriers	Frequency
BA1	Small font, screen size, font type, buttons, and color contrast	23	BA9	Menu with too many options and navigation issues	19
BA2	The small key with a small gap between them	3	BA10	Lack of efficacy support and trust	4
BA3	Lack of knowledge and experience	17	BA11	Lack of awareness	6
BA4	Drag and drop, soft keys, and multitap	3	BA12	Visibility and poor readability	7
BA5	Mobile device design	2	BA13	Device cost and Internet connection	5
BA6	Visual feedback of operation	9	BA14	Touch screen and QWERTY keyboard	9
BA7	Unlabeled and unfamiliar icon's size	9	BA15	Complex interface and function	7
BA8	Mobile text input and text entry	7			

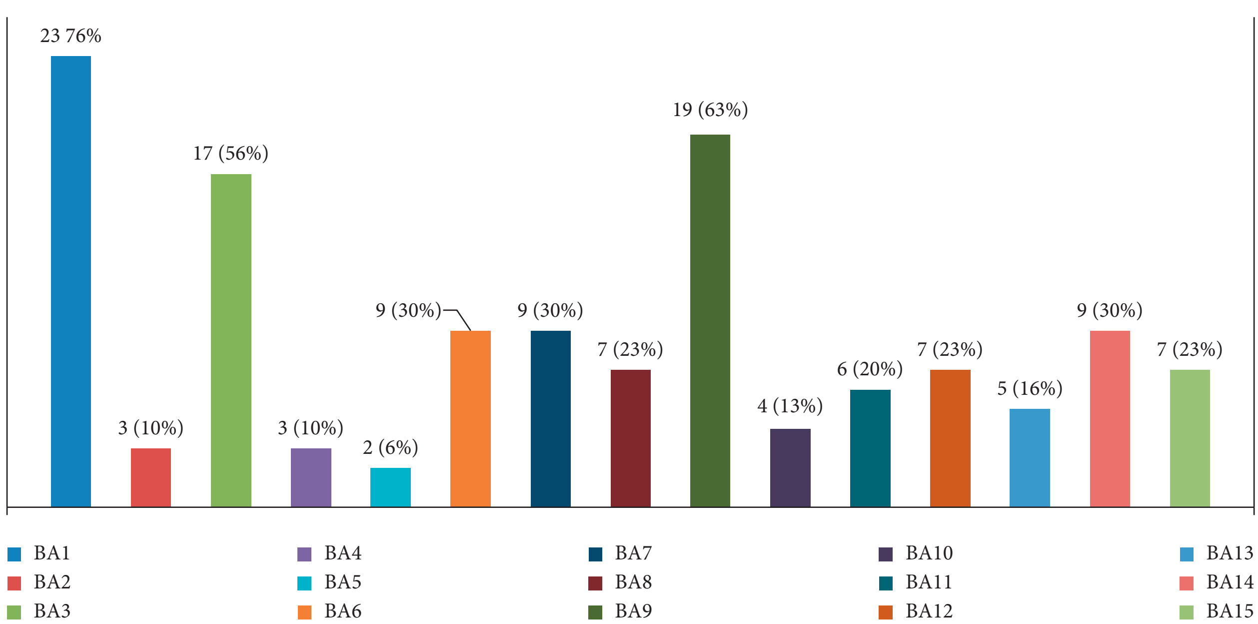

Figure 3: Barrier identification using the SLR approach.

problems with the learning ability of elderly users are associated with many factors (e.g., difficulties in cognitive ability, no awareness of computer usage, and issues related to the interface of devices) [32]. The study in [LT5] declared that poor English understanding is one of the main barriers to use smartphone devices in all genders. The authors in this research state that most of the investigated elderly users had no academic degree and for this reason; they reported the English language as a barrier to use smartphones.

A research study in [LT10] proposed that incorporating adaptive training programs with smartphone applications can be a solution to overcome the barriers to use smartphone applications. They stated that such integration of the programs will help the elderly users to efficiently use technology.

BA7 **(unlabeled and unfamiliar icon size)** was also found as one of the hard barriers to the use of smartphone applications, and it was reported by 30% of the total articles. The study in [LT8] indicates that the elderly users have quite low knowledge about modern smart devices, and they are often less aware of the device icons and their applications. They stated that the less familiarity with smart devices icons makes it hard for them to use these icons. They mentioned that our elderly users are facing more issues in using the existing smartphone icons, but attaching the semantic information with these icons and labeling it with words of its intended features can improve its use.

About 30% of the articles cited BA14 **(touch screen and QWERTY keyboard)** as a significant barrier faced by older adults while using smartphone applications. [LT48] presented that elderly users are less familiar with the use of *QWERTY* keyboards that appears as a touch screen. They elaborated that, with the increasing number of older adults involved in using technology and to have social interaction, different companies are designing more friendly touch screens. This study reported that smartphones with the advanced user interface have increased the quality of life of older adults as they feel easy in using these smartphones.

BA15 **(complex interface and function)** was discussed in 23% of the primary studies. In [LT41], an empirical study revealed that complex interface is complicated for elderly users because of their disabilities; therefore, the interface should be easy to use for elderly people and if possible help tooltips should be provided [33].

In [LT23], it was found that elder users are less familiar with the use of the Internet. They stated that elder adults are most interested in traveling, financial works, educational activities, and shopping, and due to these interests of elder people, they are often away from the use of smartphone technology.

BA8 **(text input and text entry)** has been reported by 23% of the articles selected as primary study. In [LT12], the author performed empirical studies where 15 users were involved in entering text using the devices (mobile and tablet). This experiment was conducted for measuring the performance of text entering speed and accuracy. They reported that the experimental results have proven that omissions were the most noted issues caused by cognitive load, while tablet devices reduced some challenges due to a larger keyboard. [LT1] suggests that the text input button should be aligned, and the text button should have a larger font size, which can easily be readable and approachable to older adults.

BA11 **(lack of awareness)** was found in more than 20% of the primary selected studies. [LT38] reported that the potential users of smartphone technology may not have enough knowledge about its use. In [LT48], it was mentioned that older adults generally have less awareness about the importance of new technologies. They stated that less awareness and unfamiliarity of smartphone technology creates a barrier to adopt it, and it is important to make the elders know about the technology.

BA12 **(visibility and poor readability)** was discussed in more than 23% of the selected literature. [LT16] discussed the issues of visibility and poor readability when using smart devices. The study linked the use and acceptance of smartphones among youngsters as well as elders. They reported that the aging aspect of elderly people was having problems such as poor visibility and readability of the text while using smart devices. Also, they elaborated that browsing on a small screen could be problematic for the elderly user because they face problems such as visibility, focus recognition, poor understanding, operating text, and hyperlinks' identification.

BA6 **(visual feedback of operation)** is a challenge to the usability of a smartphone device by older adults, approximately 30% of the selected articles. The literature revealed that the touch screen mobile interface depends on visual feedback; however, the ease of understanding manuals and input of the operation is hard for the elderly people.

[LT8] suggested that the feedback of the operation and manuals can help the elders to have a sense of control as they are not confident when using smartphone devices. They stated that such facilities will help them in solving the related problems if it ever happens.

BA13 **(device cost and Internet connection)** were reported in 16% of the selected articles. [LT44] performed an empirical study in which they found that the device cost is a very influential factor. They discussed that older people have a more significant concern with the costs of devices and Internet connections, and it is important to figure out their income and financial resources so that smartphones and their services can be made available infeasible cost range.

BA10 **(lack of efficacy support and trust)** was reported by 13% of our primary studies. These studies are mainly described that elderly users have the misconception that they cannot learn new technologies; therefore, they do not try to learn them. They have poor self-efficacy which is the quality by which a person trusts themselves to operate technology. The elderly users, when facing the issues of not operating the technology inefficient way, used to blame themselves. They think that such problems are occurring due to their poor learning ability. [LT14] performs an empirical study in which they found self-efficacy is an influential factor. They reported that the participants in this study were asked about their fear related to the use of technology, which they responded with a more straight answer. It was observed in this study that the elder people are having the insecurity to not openly be ashamed, and they do not want to look awkward by making certain mistakes, and such fears are making them not use new technologies.

BA5 **(mobile device design)** is also a barrier towards the adoption of smartphone devices among older people and reported 6% in the selected articles. The use of smartphones is increasing dramatically, and it makes elderly people have connections with their families and with friends on social media. The elders can make their lives easier by utilizing smartphones; however, they are yet having more issues while using them. The issues are often related to the aging problem them and the lack of familiarity with the design of different smartphone devices. Many older people struggle to use smartphone devices; this is just because of poor mobile devices design such as small buttons, small font size, design, and complicated user interface which have made older people reluctant to even use them. They also lack motivation and support from a family, which prevents them from fully utilizing smartphone devices.

BA4 **(drag and drop, soft keys, and multitap)** was reported by 10% of the primary selected articles. The literature revealed that elders are facing more issues in using soft keys and multitap compared to the youngsters, and it implies that smartphones with changing button labels and the touch and hold operation can confuse the elders.

A study conducted in [LT8] stated that soft keys and multitap are easy to use by the youngsters, but it appears much tricky for elders. They reported that elder people are found to have difficulties in developing mental models of soft keys. Also, they investigated that the multitap feature was irritating some of the elders, who were unable to understand the characters on different buttons in a standard 12-key telephone keypad.

Around 10% of the articles specified BA2 (**a small key with a small gap between them**) as a barrier to older people's use. Similarly, Dong et al. [34] suggest that interface usability problems might be a result of a combination of issues: small font size (sensory problem), confusing menus (cognitive problem), and small keys with small gaps between them (sensory and motor problem). The hypothesis for the barriers is the lack of training that poses a problem, suggesting training courses and strategies for making effective use of friends' and family's computer expertise. In [LT6], Francisco shows that, in their study, older people need more time to complete tasks on smartphones and defines problems such as the size of the screen to read information, the size of the menu, and the interface to enter data. Older people tend to make mistakes when tapping a small target, the gap between intended and actual touch location (older people tend to miss their intended targets due to parallax and large contact area of each finger).

3.2. Critical Barrier. Rockart [35] introduced the concept of critical factors to identify information. This idea is based on the perception factors derived from management literature [36]. Niazi [37] defined critical factors as the area in which organizational management focuses on achieving specific business goals. Critical factors may vary as they depend on an individual position within an organization, and critical factors may also change over time [35–37]. We used the following criteria to determine the criticality of the specific factor. If the factor has a frequency >30%, then it is considered to be a critical factor.

The criterion is used by different researchers in various areas. In this study, it was used to determine critical barriers. A total of six barriers were categorized as CBs to usability: BA1 (small font, screen size, font type, buttons, and color contrast), BA3 (lack of experience and knowledge), BA6 (visual feedback of operation), BA7 (unlabeled and unfamiliar icon's size), BA9 (menu with too many options and navigation issues), and BA14 (touch screen and QWERTY keyboard).

3.3. Categorization of the Identified Barriers. We mapped the identified barrier into five different categories. The analysis of barriers identified during this SLR study was carried out, according to which they are allocated to one of the five categories, as depicted in Table 7.

The barriers identified in the current SLR study can serve as a basis of knowledge of the respective field for practitioners and researchers. The barrier identification and classification provide a robust framework that opens up a way for the researchers and practitioners toward the most critical areas in the field. It will also assist smartphone development teams in building application effective strategies to mitigate usability barriers.

4. Proposed Methodology

Analytical hierarchical processing (AHP) is a popular technique/methodology developed by Satty, [38] used for multicriteria decisions. In this study, we used AHP techniques to identify the categories to identify the barriers and solve the problems; different researcher's also used AHP techniques to solve problems. The AHP technique consists of three steps:

Step 1: in step 1, we identify goals, categories, and barriers to our problem

Step 2: in step 2, we decompose the problem into a hierarchical structure such as Level 1 (goals), Level 2 (factors), and Level 3 (subfactors)

Step 3: find out the priority weight of every category (barrier) with the help of a pairwise comparison of a matrix; for this purpose, "9-point scale of importance" is used, which is shown in Table 8

After finding out the priority weights of each category, we check the consistency of the pairwise matrix with the help of the following equation:

$$\mathrm{CI} = \frac{\lambda \max - \mathrm{n}}{\mathrm{n} - 1}, \tag{1}$$

where CI is the consistency index, λ max is the eigenvalue of the matrix, and n is the size of the matrix. After finding the CI index, we will find out the consistency ratio with the help of the following equation:

Table 7: Categorization of the identified barriers.

S. no.	Categories	Barriers
1	Sensory function	Small font, screen size, font type, buttons, color contrast, low voice quality, unlabeled and unfamiliar icon's size, visibility, and poor readability
2	Cognition	Navigational issues, complex users' interfaces and functions, variety of mobile device design, and visual feedback of operation
3	Motor skills/ impairment	Drag and drop soft keys and multitap, mobile text input *e* entry, touch screen and virtual keyboard, and the small key with a small gap between them
4	Mental model	Lack of experience and knowledge and lack of awareness and up-to-date knowledge
5	Financial limitation	Lack of support and trust, device cost, and Internet connection

Table 8: Point scale table.

Definition	Importance
Equally importance	1
Moderate important	3
Strongly more important	5
Very strongly more important	7
Extremely strongly more important	9
Intermediate values	2, 4, 6, 8

$$CR = \frac{CI}{RI}, \tag{2}$$

where CR is the consistency ratio if the value of CR is less than 0.10; then, CR value is acceptable; otherwise, we will repeat the process, assigning priority weight to that category (barriers) until we get the acceptable value of CR, while RI is the random consistency index which is constant for a particular size of a matrix, as shown in Figure 4.

Size of Matrix	Random Consistency Index
1	0
2	0
3	0.58
4	0.90
5	1.12
6	1.24
7	1.32
8	1.41
9	1.45
10	1.49

Figure 4: Size of matrix and random consistency index.

4.1. Our Approach. According to the proposed methodology discussed in Section 4, we adopted the following steps:

Step 1: we have identified our goals, categories, and barriers.

Step 2: we divide our problem into the following hierarchical structure:

The goal is to prioritize barrier in Level 1; Level 2 consists of different categories, i.e., sensory function, cognition, motor skills/impairment and mental mode, and financial limitation. Each category is further divided into barriers (Level 3).

Step 3: in this step, we assign a weight to each category barrier according to the scale shown in Table 9 for the pairwise matrix comparison of sensory function category

Table 9: Pairwise matrix comparison of sensory function category.

Barrier	BA1	BA2	BA3	Priority weight
BA1	1.00	8.00	6.00	0.761
BA2	0.13	1.00	2.00	0.141
BA3	0.17	0.50	1.00	0.098
Sum	1.29	9.50	9.00	1

Here, we calculate

$$\Lambda \max = \frac{(1.00 * 0.761 + 8.00 * 0.141 + 6 * .0.098)}{0.761} + \frac{(0.13 * 0.761 + 1.00 * 0.141 + 2.00 * 0.098)}{0.141} + \frac{((0.17 * 0.761 + 0.50 * 0.141 + 1.00 * 0.098)/0.098)}{3}, \tag{3}$$

$$\lambda \max = \left(\frac{3.26 + 3.05 + 302}{3}\right) = 3.11.$$

Now, the value of CI is

$$CI = \frac{\lambda \max - n}{n - 1}, \tag{4}$$

where n is the size of the matrix.

$$CI = \frac{3.11 - 3}{3 - 1} = 0.056. \tag{5}$$

CR is calculated as

$$CR = \frac{CI}{RI},$$
$$CR = \frac{0.056}{0.58}, \quad (6)$$
$$CR = 0.096\,CR = 0.096 < 0.10.$$

In Table 10, $\lambda\max = 4.217$ $CI = 0.072$, and $RI = 0.9$:

$$CR = 0.081 < 0.10. \quad (7)$$

In Table 11, $\lambda\max = 4.116$ $CI = 0.039$, $RI = 0.9$, and $CR = 0.043 < 0.10$.

In Table 12, $\lambda\max = 4.006$ $CI = 0.002$, $RI = 0.9$, and $CR = 0.002 < 0.10$.

In Table 13, $\lambda\max = 4.196$ $CI = 0.065$, and $RI = 0.9$:

$$CR = 0.072 < 0.10. \quad (8)$$

Local ranking means the position of a particular barrier in its category and global ranking means the position of a barrier in all 5 categories. Here, the barrier BA1 "small font, screen size, font type, buttons, and color" is found to be the most significant barrier among other barriers, while barrier BA10 "lack of efficacy support and trust "is found to be the least important barrier. The ranking of the different local and global barriers in and among different categories is shown in Table 14.

The usability barriers' summary list is regarding smartphone applications used by old people, which is based on the importance in all categories and is shown in Table 15. Barrier BA1' small font, screen size, font type, buttons, and color contrast' has the highest priority. Barrier BA15 "complex interface and function" is the 2nd critical barrier [30, 33, 39]. BA6 "Visual feedback of operation" is the third higly cited usablity barrier in the reported literature [32].

Table 10: Pairwise matrix comparison of cognition category.

Barriers	BA4	BA5	BA6	BA7	Priority weight
BA4	1.00	4.00	0.14	0.33	0.161
BA5	0.25	1.00	0.25	3.00	0.184
BA6	7.00	4.00	1.00	2.00	0.474
BA7	3.00	0.33	0.50	1.00	0.181
Sum	11.25	9.33	1.89	6.33	1

Table 11: Pairwise matrix comparison of motor skills/impairment category.

Barriers	BA8	BA9	BA10	BA11	Priority weight
0BA8	1.00	4.00	5.00	0.20	0.320
BA9	0.25	1.00	5.00	3.00	0.310
BA10	0.20	0.20	1.00	0.33	0.053
BA11	5.00	0.33	3.00	1.00	0.318
Sum	6.45	5.53	14.00	4.53	1

Table 12: Pairwise matrix comparison of motor mental model + financial limitation category.

Barriers	BA12	BA13	BA14	BA15	Priority weight
BA12	1.00	5.00	6.00	0.20	0.262
BA13	0.20	1.00	5.00	0.13	0.132
BA14	0.17	0.20	1.00	0.50	0.096
BA15	5.00	8.00	2.00	1.00	0.510
Sum	6.37	14.20	14.00	1.83	1

Table 13: Pairwise matrix comparison between categories.

Category	Sensory function	Cognition	Motor skills	Mental model/ financial limitation	Priority weight
Sensory function	1.00	5.00	7.00	3.00	0.513
Cognition	0.20	1.00	6.00	0.25	0.168
Motor skills	0.14	0.17	1.00	2.00	0.123
Mental model/ financial limitation	0.33	4.00	0.50	1.00	0.197
Sum	1.68	10.17	14.50	6.25	1

5. Discussion

We identified 53 articles that hold one or more factors hindering the adaptation of smartphone applications by elderly users. To answer RQ1, a total of 15 barriers were identified from 53 selected articles for the SLR. Areas represented by the identified barriers were those which need the main focus of development teams and designers to mitigate the issues faced by elderly people while using smartphone devices. To solve the RQ2, the criteria described in Section 3.2 were applied to determine the criticality of each barrier. In this study, overall six barriers were identified as critical barriers.

Our identified barriers were considered to be critical, as their frequencies were ≥30% of all those identified ones. To solve RQ3, classification of the identified barriers was done, assigning categories according to sensitivity. Most of the barriers were placed in the "sensory function" category (Table 6) as these are the most essential area to be addressed.

Multiple-criteria decision analysis methods (MCDA) can be divided into three categories: cost/value measurement models, reference-level models, and top-level models. The AHP utilized MCDA technique relatively similar to the value measurement model, as the scores are developed for each barrier and grouped into higher level models. In this study, we present the application of the AHP to scale different usability barriers in smartphone application for elderly users. The performance seems to improve rather than depend on qualitative analysis alone. AHP uses pairwise comparison matrix to determine the priority weight and costs of each barrier. In addition to the identified barriers, the focus is on development teams and designers to alleviate the problems faced by the elderly when using smartphones.

Table 14: Local and global ranking of barriers.

S. no.	Barrier	Category	Category priority weight	Priority weight	Local ranking	Global weight	Global ranking
1	BA1	Sensory function	0.513	0.761	1	0.390	1
2	BA2			0.141	2	0.073	4
3	BA3			0.098	3	0.050	6
4	BA4	Cognition	0.168	0.161	4	0.027	12
5	BA5			0.184	2	0.031	10
6	BA6			0.474	1	0.080	3
7	BA7			0.181	3	0.030	11
8	BA8	Motor skill	0.123	0.320	4	0.039	7
9	BA9			0.310	2	0.038	9
10	BA10			0.053	1	0.007	15
11	BA11			0.318	3	0.039	8
12	BA12	Mental mode + financial limitation	0.197	0.262	2	0.052	5
13	BA13			0.132	3	0.026	13
14	BA14			0.096	4	0.019	14
15	BA15			0.510	1	0.100	2

Table 15: Prioritization of barriers.

Barrier	Name of barrier	Priority	Barrier	Name of barrier	Priority
BA1	Small font, screen size, font type, buttons, and color contrast	1	BA9	Menu with too many options and navigation issues	9
BA15	Complex interface and function	2	BA5	Mobile device design	10
BA6	Visual feedback of operation	3	BA7	Unlabeled and unfamiliar icon's size	11
BA2	The small key with a small gap between them	4	BA4	Drag and drop, soft keys, and multitap	12
BA12	Visibility and poor readability	5	BA13	Device cost and Internet connection	13
BA3	Lack of knowledge and experience	6	BA14	Touch screen and QWERTY keyboard	14
BA8	Mobile text input and text entry	7	BA10	Lack of efficacy support and trust	15
BA11	Lack of awareness	6			

In AHP process the problem is decompose into the hierarchical structure, i.e., Level 1 (goal), Level 2 (factors), and Level 3 (subfactors). We assign weight to each barrier according to the scale for pairwise comparison. We cluster a series of barriers that is categorized as local and global ranking. The barrier BA1 ″small fonts, screen size, fonts, buttons, and colors" is considered the most important barrier among other barriers, and BA10 ″lack of support for efficiency and trust" is considered the least important barrier. The primacy of certain factors as obstacles does not mean that other factors are not important or will not affect the development of the system.

6. Conclusion

Today smartphone devices are very helpful for elderly users to have a healthy, safe, and sound lifestyle. This kind of technological appliance makes them independent and more socially active with having an easy connection with their loved ones, which can improve the quality of their life. Technology is gaining increased potential values in daily life. However, some shortcomings are there in assessing elderly people's lifestyles, needs, and expectations, as technology is not being widely adopted among them because of the usual awareness knowledge in this area. Therefore, it is very necessary to consider the need and requirements of elderly users in the design and development phase of a smartphone application.

With the rapid increase in smartphones application in today's society, we are motivated to elaborate and identify the barriers that present a challenging situation to elderly people in the usability of mobile computing devices and relevant technologies.

In this research, AHP approach is used to identify various barriers to usability issues in elderly people. Total of 15 barriers were identified by using SLR approach. The critical barriers among the identified ones include small font size, screen size, font type, buttons, color contrast, touch screen, and QWERTY keyboard. Others include lack of experience and knowledge, visual feedback of operation, unlabeled and unfamiliar icon's size, menu with too many options, and navigation issues.

In this study, AHP was proposed to prioritize the categories and factors for the identification of key barriers. The Barrier BA1′ small font, screen size, font type, buttons, and color contrast' have the highest critical value, while Barrier BA15 ″complex interface and function" is the 2nd critical barrier. The results are the main issues which should be considered to reduce the barriers in smartphone application.

These barriers were identified as critical, which can provide guidelines for the device designers and development team to mitigate the usability issues to older people.

We will apply fuzzy AHP for the same dataset for more enhancement results.

Data Availability

The data collected during the data collection phase are available from the corresponding author upon request.

Conflicts of Interest

The authors declare that they have no conflicts of interest.

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